SOUTH KOREAN SECONDARY BATTERY TECHNOLOGY CRITICAL TO GLOBAL NET ZERO

Kumyang

OXFORD METRICA

ABOUT OXFORD METRICA

Oxford Metrica is a strategic advisory firm, offering informed counsel to boards.
Our advisory services are anchored on evidence-based research in risk and financial performance.
Our work includes statistical analysis and index construction for banks and insurers, risk and performance analytics for asset managers, due diligence support in mergers and highly customised services for corporate boards.

ABOUT KUMYANG CO., LTD.

Kumyang Co., Ltd. is a world leading producer of blowing agents and related products, headquartered in Busan, South Korea. Founded in 1955, and listed on the KOSPI since 1976, Kumyang now serve over 7,000 customers in 76 countries and own and operate several facilities across Asia; the US; and Europe. Their customers include the likes of BMW; Nike; and Adidas. Kumyang is also investing heavily into new areas such as cylindrical battery production and materials. The company acquired a lithium mine in Mongolia (June 2023) and another in the Democratic Republic of Congo (December 2022) to secure a stable supply of the metal. Through these strategic acquisitions, Kumyang controls the entire secondary battery supply chain and is rapidly becoming a pioneer in green technology innovation.

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FOREWORD

Francis Knight has been a Principal at Oxford Metrica since September 2022, supporting the company's overall business development and strategy. He also plays a leading role in the management of all project requirements including research; data interpretation & configuration; and final write-up & presentation. Francis began his career in asset management spending two years at the Hong Kong investment manager, Value Partners, based in London. Francis holds an MSc Accounting & Finance from Imperial College Business School and was awarded the Investment Management Certificate (IMC) in 2019.

The Lithium-ion Battery (LiB) was first commercialised for public use in consumer electronics in 1991. Since then, LiB manufacturing has proliferated immensely, with the batteries having become the energy storage solution of choice for a myriad of applications including, amongst others, uninterrupted power supply (UPS) systems; medical devices; smartphones; e-scooters; and currently its most topical use, electric vehicles (EVs), which acts as a core theme throughout this report.

This whitepaper aims to provide an overview of the long-term global demand for both EVs and LiBs, given that these two industries are inextricably linked; an insight into current industry dynamics; whilst also identifying the major players in both EVs and LiBs. Oxford Metrica has been ebullient on South Korea for over two decades owing to, amongst other reasons, its exceptional economic growth since the founding of the Republic in 1953. The two aforementioned industries no doubt played a huge role in Korea becoming the economic success it is today, being one of only two countries in the world (the other being China) that features in both the top ten individual EV and LiB producers. Moreover, as is discussed below, current developments – both political and technological – are affording Korea a unique window of opportunity to wrestle market share from China in the LiB sector.

Determined to lead Korea on this drive is Kumyang. With its stellar track record and reputation in the chemicals sector; infrastructure; intellectual expertise it has acquired over many years; and its long-term vision, it is now striving to become the pre-eminent provider of cylindrical LiBs, that maximise power; range; and safety. An overview of Kumyang as well as its latest strategic developments and innovations are presented herein.

LiBs are fundamentally ubiquitous in our daily lives today and almost entirely indispensable. We hope that this paper provides interesting insights into this dynamic fast-evolving sector which, regardless of the ultimate victors, will have a positive effect on humanity in our collective quest to abate the negative effects of climate change.

Francis Knight
Principal
Oxford Metrica

PREFACE

Dr Rory Knight, is the Chairman of Oxford Metrica. Rory is a member of the John Templeton Foundation where he chaired investments. Formerly he was Dean of Templeton College, Oxford University's business college and before that the Vize-Direktor at the Schweizerische Nationalbank (SNB), the Swiss central bank.

The market for Lithium-ion batteries (LiBs) is increasingly dominated by China which enjoyed a market share of more than 60% in 2023. In that year Korea was ranked the second largest producer with a market share of 28%. Korea lost market share from 2022 when it held around 45% of the market.

The current white paper sets out to demonstrate that China's dominance is likely to be strongly challenged by the re-emergence of Korea as a force in LiB production. There are three key change vectors that coalesce to favour Korea reasserting its position in the LiB market.

Firstly, the geo-politics of deglobalisation will weaken China. The United States, Canada and the European Union have all recently imposed significant tariffs on Chinese manufactured electric vehicles. Korea has free trade agreements (FTAs) which will strengthen its competitive position *vis à vis* China.

Secondly, the Korean government has demonstrated a strategic commitment to the LiB industry. Recently, government incentives amounting to the equivalent of US dollars 38bn were announced. This investment includes developing the full value chain of production and recycling in addition to research funds to keep Korea on the leading edge of battery technology.

Thirdly, a new force is emerging in the Korean LiB production industry. Busan-based Kumyang, a long-established chemical firm, is about to introduce significant additional capacity with a superior technology.

This white paper begins with an analysis of the long-term demand dynamics for both battery-powered electric vehicles (EVs) and LiBs, including a description of the top ten players in both sectors. After a primer on LiBs, the paper lays out the opportunities and challenges facing Korean LiB producers. The paper concludes with sections on Kumyang and its new technology.

We at Oxford Metrica are delighted to have collaborated with Kumyang on this project and I hope that you will find the insights useful.

Dr Rory Knight
Chairman
Oxford Metrica

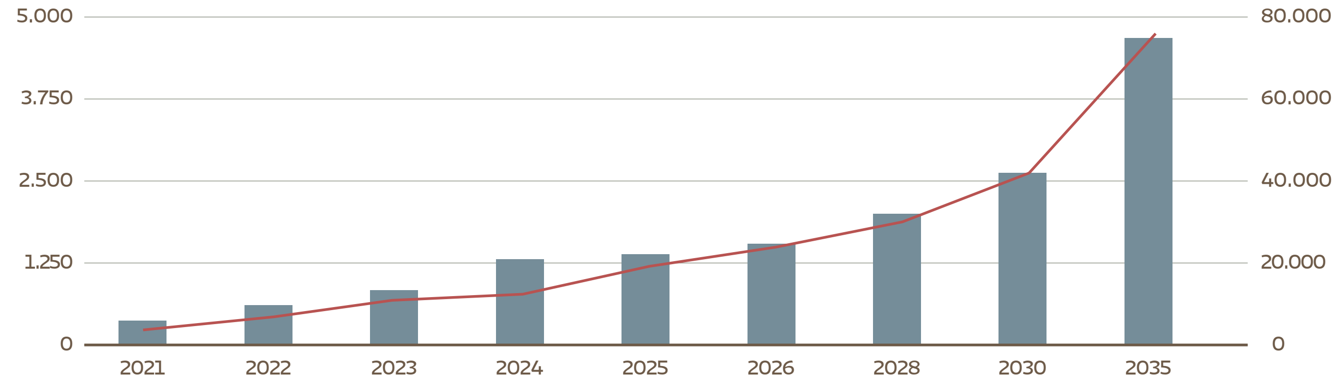
THE LONG-TERM DEMAND FOR ELECTRIC VEHICLES AND LITHIUM-ION BATTERIES

Over the last decade, the global demand for electric vehicles (EVs) has exploded and EVs make up the largest segment of new auto sales in most major markets around the world.[1] Tesla, the largest producer of EVs, has enjoyed a compound growth in dollar sales of 35% per annum over the last 6 years with revenues approaching $100 billion in 2023. Tesla's production of Electric Vehicles (EV) in 2023 amounted to over 1.8 million units representing a market share of over 20%. As reported in the next section, the world's top twenty producers of EVs currently produce over 8 million units a year and notwithstanding a slight slowing in growth during the first two quarters of 2024, long-term forecasts are extremely healthy.

As described opposite, the Lithium-ion Battery (LiB) dominates the market for EVs and indications are that it will continue to do so for the next decade. There are three main reasons for this domination. Firstly, the LiB is a superior technology with physics, chemistry and material science on its side. It would take a brand new and unexpected technology to sweep it away. This is of course possible, if unlikely, for the following reasons. Firstly, the current contenders to replace it are nascent at best and without the performance LiB enjoys. Secondly, the dominance is further embedded as there is a dynamic and competitive market in LiB battery production with billions of dollars being invested in research and development to further improve the LiB's performance. Thirdly, the EV manufacturers have committed to production facilities to accommodate the LiB, creating switching costs as a further barrier to entry to any new technology. What is of course less certain is the identity of the winners and losers in both LiB and EV production over the next decade. An example of a potential disrupter is Kumyang an exciting new South Korean entrant in the LiB market with a superior technology and a large-scale production facility. The LiB market is dominated by ten producers (see Table 2) from China, Korea and Japan. China currently dominates however geo-political changes and de-globalisation trends might change this as the US and Europe take a more protectionist position on international trade. This will favour Korea and Japan who both have free trade agreements with both the US and the EU. Over the next decade, the landscape of LiB production is likely to change however the aggregate demand for LiBs generated by EV is reasonably stable. Furthermore, since China imports no LiBs a drop in trade links asymmetrically favours Japanese and Korean LiB producers, which will be well placed to take up the demand displaced from China. The net effect is demonstrably beneficial to Japan and Korea. Recent forecasts from the reputable SNE Research in Seoul show a 26% compound annual growth in demand for LiBs over the next decade. Figure 1 shows that EV production will grow to around seventy million units from the current level of around seventeen million. This will create a strong demand and increase in production in LiBs from the current level of around seven hundred Giga Watt hours (GWh) to four thousand five hundred GWh per annum in 2035.

FOOTNOTES are on page 36

FIGURE 1 Forecast of the supply and demand for Lithium-ion batteries



Lithium-ion battery...the Lion King

"Lithium-ion batteries have revolutionised our lives since they first entered the market in 1991. They have laid the foundation of a wireless, fossil fuel-free society and are of the greatest benefit to humankind."

— The Royal Swedish Academy of Sciences announcing the Nobel Prize in Chemistry 2019

There is little doubt that the Lithium-ion battery (LiB) dominates the battery world and for good reason – it has proven to be the most efficient rechargeable energy storage device with a wide variety of ubiquitous applications, from electronics, mobile phones and now electric vehicles. Its properties provide battery-powered electric vehicles (EVs) with the critical features of functionality for commercial success. The key properties of high specific energy and high power density provide EVs longer range and faster acceleration through faster charging. The quality of the electrochemical processes (electrolyte) in the LiB are currently providing EVs a service life of up to 10 years. The cost considerations are significant and currently, the cost of the batteries is the largest part of the powertrain and represents around one-third of the total cost of the EV. Further economies are required to bring down the retail price of EVs.

Although there have been significant performance improvements, the fundamental structure of the LiB (see diagram) remains much as it was when invented in Oxford in 1980 [Goodenough *et al* 1980]. John Goodenough and his team at the University of Oxford, proposed a LiB using a Lithium Cobalt oxide cathode ($LiCoO_2$), building on the prior work of M. Stanley Whittingham, also of Oxford. Professor Whittingham had earlier proposed an LiB with a Lithium Aluminium anode combined with a Titanium disulfide cathode. Although, Whittingham's battery was unstable his conception of the intercalation remains a central feature of the modern LiB. Intercalation is the process by which Lithium ions are able to be inserted, stored and retrieved efficiently from the anode and cathode. Professor Goodenough requested Oxford University to register the patents for the LiB, however they turned down the request. The British Atomic Energy Research Establishment (AERE) did register the patents and Goodenough received no compensation. The AERE finally sold the license to Sony for around ten million pounds in 1991. The head of research at Sony, Dr Akira Yoshino developed a more efficient graphite anode and the first commercial version of the LiB appeared on the market in 1991. Whittingham, Goodenough and Yoshino were jointly awarded the Nobel Prize in Chemistry in 2019. At ninety-seven years old Professor Goodenough is the oldest recipient of a Nobel prize.

Much of the innovation within the LiBs for EVs market over the last 33 years has been with regard to materials used for the cathode. Currently, five different cathode forms are in commercial use each of which provides different trade-offs of the desirable attributes for EVs. These are:

1. **NMC** (*Lithium Nickel Manganese Cobalt Oxide*) has a well-balanced set of attributes among energy density, lifespan and safety. NMC is the most common cathode and it is produced by almost all of the major LiB suppliers and used by most EV manufacturers.
2. **LMO** (*Lithium Manganese Oxide*) has moderate energy density (low range) however it does exhibit good thermal stability and enjoys a high-power output. It is often used with NMC (see below). Samsung SDI is a prominent producer mainly for the European EV market.
3. **NCA** (*Lithium Nickel Cobalt Aluminium Oxide*) exhibits a high energy density combined with a long lifespan; however, it is considered to be less stable than the other variants. The main producer is Panasonic which supplies Tesla for some of its models.
4. **LFP** (*Lithium Iron Phosphate*) exhibits excellent thermal stability combined with a long lifespan; however, its energy density is less than the standard set by the original Lithium Cobalt Oxide battery. The two main producers are the Chinese firms CATL and BYD. The former produces this battery type for some of Tesla's models produced in China and the latter uses it for its own vehicles.
5. **NCMA** (*Lithium Cobalt Manganese Aluminium*) is the most advanced and is an emerging variant which delivers high energy density, long lifespan, increased recyclability, and high safety levels at a reduced cost. The introduction of Aluminium reduces the more expensive Cobalt content and further stabilises the cathode. Nickel increases energy density. Kumyang, a new South Korean entrant to the LiB market is producing an enhanced NCMA with a much higher-grade Nickel (97% pure) in a single crystal structure. This is entering production at scale as the 4695 cylindrical battery. The only comparable LiB is Tesla's 4680 tabless battery which it produces for its own use. The 4680 currently constitutes less than 10% of its battery consumption. Further advances in cathode technology will likely see a Cobalt-free version and a Sodium based cathode.

The anode in all versions is Graphite-based. Innovation in the anode technology seems to revolve around adding increasing amounts of Silicon to the Graphite which is likely to lead to a pure Silicon anode in the next few years which will extend the lifespan significantly.

The electrolyte is the liquid medium which transports the ions from the anode to the cathode during discharge and the opposite way during charging. The electrolyte makes up between 10% and 15% of the weight of a LiB and consists of a mixture of lithium salts such as lithium hexafluorophosphate ($LiPF_6$) dissolved in an organic solvent. The quality of the electrolyte largely determines the life of the battery.

The holy grail of electrolyte innovation is a solid-state format which is likely to emerge in the next few years.

The final constituent of the LiB is the separator which is required to keep the two electrodes apart while allowing the free flow of lithium ions. The separator is usually made from polymers such as polyethelene (PE) and polypropelene (PP). The key properties required of a separator are high insulation to prevent short-circuits, porosity to ensure a high level of conductivity and thermal stability in high temperatures.

LiBs come in three different formats across all cathode types (see *Lithium-ion Battery Form Factors*). These are:

1. **Cylindrical** form which has superior thermal stability with reduced thermal propagation. However, being of a standard size, it has limited design versatility. The Kumyang 4695 and the Tesla 4680 are examples of this form.

2. **Pouch** form which is sleek and lightweight with customizable design. However, this form exhibits high thermal strain and limited heat tolerance. The Pouch is popular with Korean LiB manufacturers and EV producers.

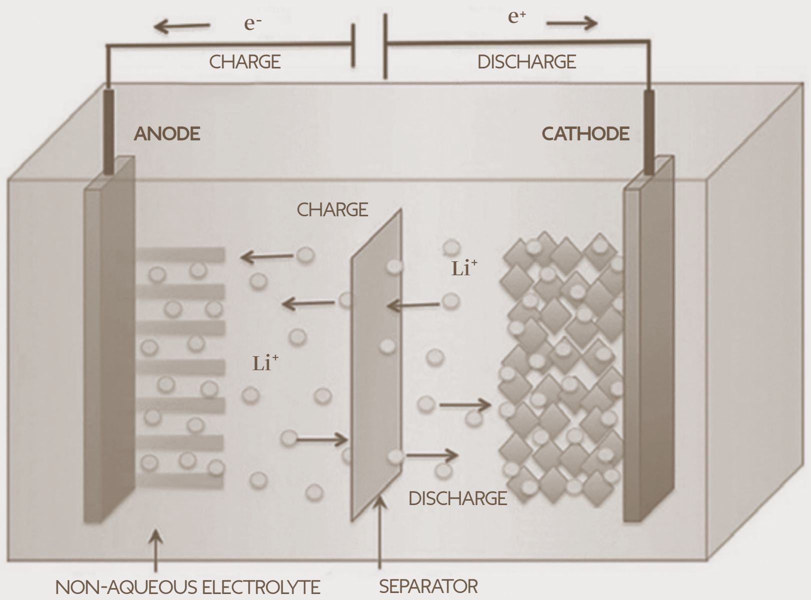
3. **Prismatic** form lies somewhere between the other two; sleeker than the Cylindrical, with more design flexibility but less so than the customisable Pouch. The production costs are higher than the Cylindrical. BYD, the major Chinese EV producer uses this form and manufactures it in-house.

The LiB market is technically dynamic and highly competitive, with the world supply coming from only three countries, China (63%), South Korea (28%) and Japan (9%).

There are a number of non-lithium alternatives being researched such as Sodium-ion (lower energy density than LiB); Lithium-Sulfur (limited lifespan); Zinc-air batteries (limited rechargeability); Magnesium-ion (inefficient ion transport); Aluminium-ion (low energy density); Nickel-Hydrogen (Complex design and expensive); Flow batteries (low energy density) and a number of others which are unlikely competitors to the traditional and rapidly improving Lithium-ion battery which is attracting considerable research expenditure as they are currently commercially viable and are likely to dominate for the next decade.

The Lithium-ion battery is definitely the Lion King and is likely to reign for some time.

DIAGRAM SOURCE: Ghiji *et al*



THE TOP TEN ELECTRIC VEHICLE MANUFACTURERS

Four of the top ten manufacturers, by EV unit production in 2023, are in China; three are in Europe; two are in the US; and one is in Korea. In addition, Chinese producers take up six of the places in this ranking between rank eleven and twenty. Table 1 reports summary data on these top ten manufacturers. Clearly, China currently dominates.

Tesla, the US producer established in 2003, holds on to the top position with over 1.8 million units in 2023. The company at one stage was among the five most valuable companies in the world with a market capitalisation of over one trillion dollars. Tesla's Model X was the first EV to pass one million in sales and the Model Y was the only EV to be the best-selling car in the world. Tesla has several production facilities (Gigafactories) in the US and in 2022 opened a Gigafactory in Germany which currently produces the Model Y for the European market. Tesla currently has a market share of more than 20% of the top twenty producers. Tesla is the only top ten producer that was newly purpose-built for EV production. As a brand-new facility, it does not have the legacy baggage of producing fossil-fuel autos.

BYD, the Chinese producer, was a battery maker established in 1995 that extended downstream to produce EVs. Interestingly, Tesla and BYD, the only two that have no links with fossil fuels produce around 50% of the top ten production. The other producers in Table 1 are all legacy auto producers. This illustrates how extraordinarily difficult it is to pivot from legacy auto to EV. The EV% column in Table 1 reports the percent of total sales generated by EVs. Tesla is on an EV% of 100% and BYD is on 49% as it continues to be a major battery producer alongside producing EVs. BYD was the largest producer in 2022 having expanded production and is clearly neck and neck with Tesla for the top slot. BYD has to date only produced in China, however, it has global expansion ambitions and opened a production facility in Hungary in 2023. Tesla and BYD have the largest market capitalisations at $650.7bn and $89.5bn respectively. Tesla has a valuation more than double the combined value of the other nine peers in the top ten. Tesla is traded on Nasdaq and BYD on the Shenzhen stock exchange (SZSE) and it is quoted on the OTC markets in the US.

Third on the list is **Volkswagen** (VW) the German auto producer which interestingly produced the first EV in the 1970s, it was called the Elektro Transporter (ET) with a range of 40 miles and a recharge time of ten hours. Although early in the experimental phase VW is the leading European producer, it has now made EV production a major focus and it has several models. EV% is only 7% for VW which is understandable given the size of their legacy business. VW has a market capitalisation of $53.5bn and it is traded on the Frankfurt Stock Exchange (FWB) and is quoted on the OTC markets in the US.

General Motors (GM), the major US automotive company, produced an early EV called the EV1 in the 1990s and although popular was scrapped. GM has recently indicated that it is not only focused on EVs but that it will discontinue the production of its legacy fossil-fuel automobiles by 2035. This illustrates the strong potential demand for LiBs argued in the previous section, and given that GM's current EV% is only 10% there will need to be a significant growth in EV production to replace the legacy production. This augurs well for LiB demand in general and GM's current supplier of LiBs, LG Energy Solutions (LGES) one of the key Korean producers. GM is listed on the New York Stock Exchange (NYSE) with a market capitalisation of $47.2bn.

GAC (Guangzhou Automobile Group) is in fifth place after enjoying growth of over 70% between 2022 and 2023. This is an important long established (founded in 1954) legacy auto producer in China however it has yet to penetrate the US market despite its global ambitions. It has an EV% of 14% and it is traded on the

Shanghai Stock Exchange (SSE), the Hong Kong Stock Exchange (HKSE) and the OTC markets trading at a market capitalisation of $9.2bn. GAC is definitely an up-and-coming participant in the Chinese EV market.

Geely Auto Group is in sixth place another established Chinese auto producer that is focusing on the EV market. It is extremely well placed to penetrate the US market as it owns *inter alia* Volvo the Swedish car company which has production facilities in the US thus potentially allowing it to avoid tariffs on Chinese imports. Geely's EV% is 14%. Geely is listed on the HKSE and trades on the OTC markets with a market capitalisation of $9.9bn.

Hyundai Motors the only Korean in the top ten is in the seventh rank, again another legacy manufacturer it is the third largest automobile manufacturer in the world. Hyundai owns the Kia brand. Its Ioniq EV model was launched in 2020. Its current EV% is 6%. It has made a strong commitment to EV production and aims to be in the top three by 2030. It recently announced a massive investment in production facilities in Korea of $50bn, which is almost as large as its market capitalisation of $57.6bn. This is an extremely strong commitment and reflects the role that Korea will play in the future of the industry. Hyundai is traded on the Korean Stock Exchange (KRX) with a GDR on the London Stock Exchange (LSE).

BMW Group is the other major German legacy luxury auto producer in the top ten coming in at eighth with sales of 378,722 EV units in 2023. Unsurprisingly its EV% is under 10%, it is expecting this to rise to 30% by 2025. It has set a very high target of ten million EVs by 2030. Again, this underlines the outlook discussed in the previous section. BMW owns the British brands Mini and Rolls Royce both of which will have an EV on the market. Mini already has and Rolls Royce will soon be launching an EV – the Rolls Royce Spectre. BMW has a market capitalisation of $56.8bn and is listed on the FWB and quoted on the OTC markets in the US.

Stellantis was recently formed through a massive merger of the Italian Fiat-Chrysler group and PSA the French automotive company. PSA was itself formed from a merger with French auto firms Citroën and Peugeot. It is traded in Amsterdam on the Euronext market, the NYSE in New York and on the Borsa Italiana in Milan with a market capitalisation of $48.3bn. It is currently ninth on this list with sales of 348,422 units and an EV% of 5%. It has ambitious plans aiming for five million units by 2030 representing an EV% of 100% in Europe and 50% in the US.

SAIC (Shanghai Internal Combustion Engine Components Company) is the sixth of the Chinese auto companies on this list at tenth place. SAIC is a long- established (founded in 1954) legacy auto company. It has major joint ventures with VW and GM and in 2005 bought the British Rover MG brand. It is at the forefront of the EV market with several brands and the third highest EV% of 19%. It is clearly committed to the EV market with current production levels at 292,032 units. It has a market capitalisation of $6.3bn, the smallest on the table and it is traded on the SSE.

Although China enjoys a dominant position in EV production many of the foreign EV firms have significant production facilities in China as well. These include brands such as Volvo (Geely-owned), Citroën (Stellantis), the Smart car (Mercedes), Lotus (Geely-owned) and Tesla. Geo-politics will however soon change the landscape and both the US and the EU are introducing significant tariffs for Chinese producers. The European Commission has recently announced tariffs on Chinese-manufactured EVs. The lower tariffs will be levied at 20% (BYD, Geely, Tesla China) with a maximum of 38.1% (SAIC). The differential rate depends on the degree of cooperation the producer offers the Commission with their investigation. Nevertheless, these are significant tariffs which will seriously disrupt the market and provide the Korean EV and battery producers a considerable competitive advantage. The result will be a very different market share picture in 2025 and beyond.

LITHIUM-ION BATTERY SUPPLIES

Table 2 provides details on battery suppliers, the type of cathode and the form of the LiB. A striking feature is that almost all the EV manufacturers outsource LiB production and purchase from multiple suppliers, up to five in the case of VW and three is about average. Obviously, supply chain risk management is part of the multi-supplier phenomenon. However, it may be related to tailoring specific suppliers to specific models which have different battery requirements not provided by any one supplier. This is an unusual market structure due to a lack of standardisation in LiBs. The exception is BYD which has only one supplier, itself. BYD is a battery producer that brought EV production in-house, as it were, this provides a huge design advantage and is part of the reason for BYD's incredible growth. The economies of scale and design are significant. Tesla on the other hand partners very closely in production with Panasonic in the manufacturing of the 21700 cylindrical battery, however it purchases the LFP battery from CATL for its production in China. In addition, Tesla produces its new 4680 battery in-house. Interestingly, Tesla and BYD are the only two in the top ten that produce LiBs internally to any extent.

Another interesting feature of the interrelationships between EV and LiB producers is that both the Chinese and Korean EV producers use only local battery makers. This is quite natural from a cost and risk management point of view and the rather obvious reason that Europe and the US do not have national champions in LiB production. Some of the Asian LiB producers do have factories close to their customers such as Panasonic in the US.

The NMC-type cathode is dominant by supplier/customer count but not necessarily by volume. Tesla uses mainly NCA and BYD increasingly uses LFP. It is very likely that this market structure will change as the market matures and the industry converges on an optimal LiB format. The race is on among the battery suppliers.

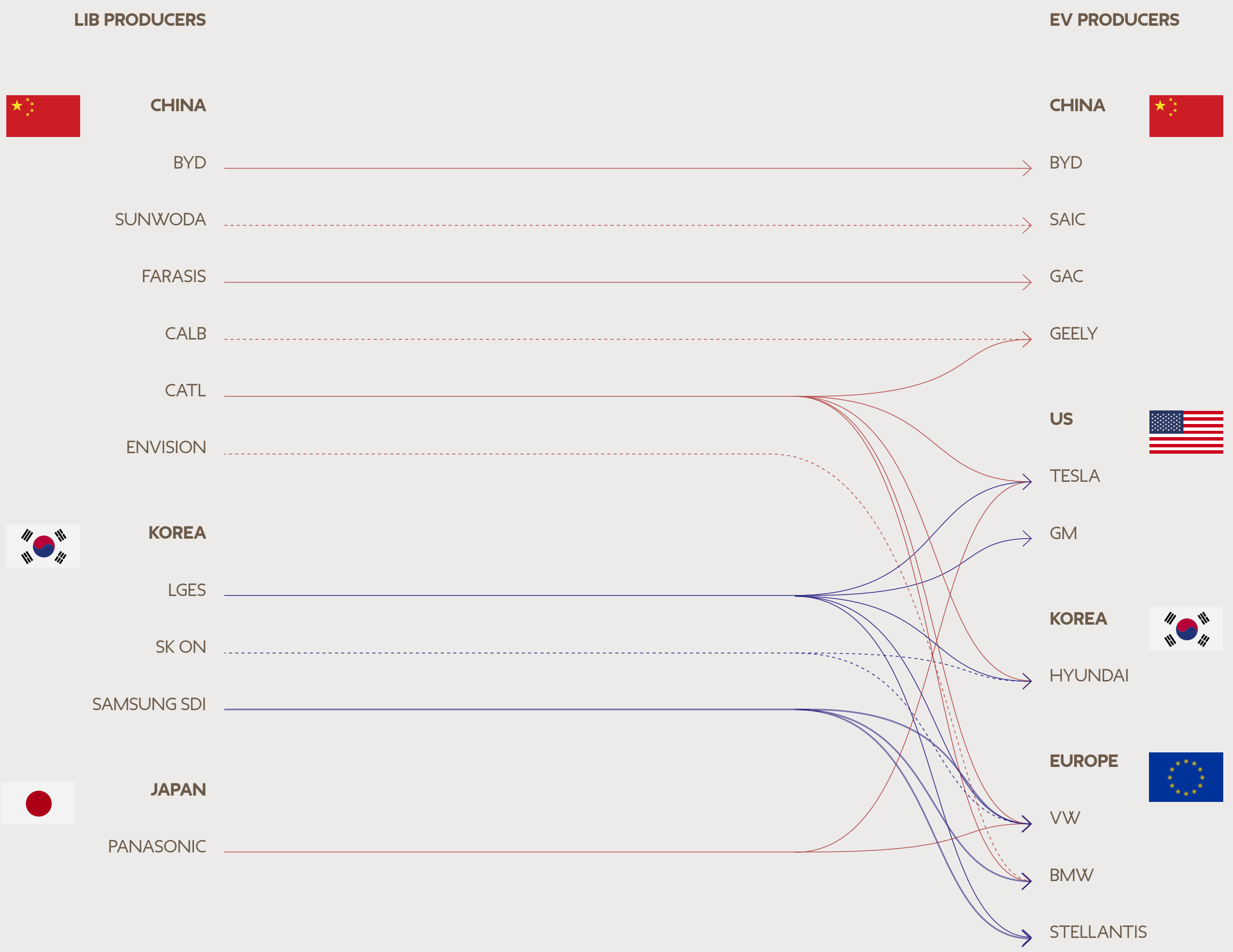
Clearly, the LiB is the most critical component in the powertrain and constitutes a significant proportion of the cost of producing and maintaining an EV. Furthermore, since the growth in the LiB market is heavily dependent on the success of the EV market it is very likely that in the next few years there will be a consolidation in the LiB market and possible acquisitions by the EV producers.

The next section provides a review of the top ten LiB producers where we will explore further the linkages among LiB suppliers and EV manufacturers which are laid out schematically on the following two pages.

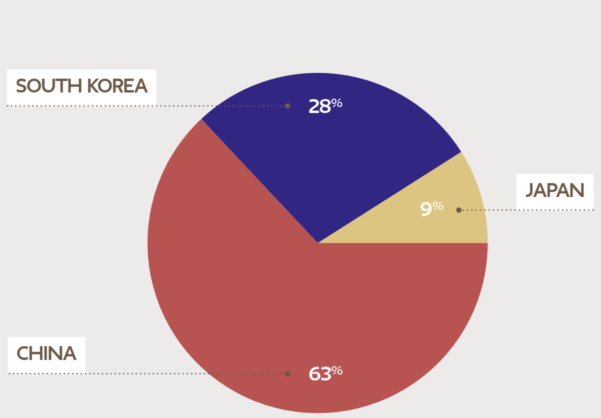
TABLE 1 The top ten battery electric vehicle producers by 2023 production (units)

RANK	MANUFACTURER	COUNTRY	PRODUCTION 2023 (UNITS)	MARKET SHARE	ORIGIN	EV%	BATTERY SUPPLIER	CATHODE	FORM	MARKET CAPITALISATION ($BN) (11/8/24)	LISTINGS	TICKER #
1	TESLA	US	1,811,088	21%	NEW	100	PANASONIC CATL LGES TESLA 4680	NCA LFP NMC NCA	CYLINDRICAL	650.7	NASDAQ	TSLA
2	BYD	CHINA	1,572,983	18%	BATTERY	49	BYD	NMC /LFP	PRISMATIC	89.5	SZSE OTC	SZ: 002594 BYDDY
3	VW	GERMANY	758,210	9%	LEGACY	7	LGES SK ON CATL SAMSUNG SDI PANASONIC	NMC NMC NMC NMC NCA	PRISMATIC	53.5	FWB OTC	VOW.F VWAGY
4	GM	US	641,162	8%	LEGACY	10	LGES	NMC	POUCH	47.2	NYSE	GM
5	GAC MOTOR	CHINA	499,495	6%	LEGACY	14	CATL CALB FARARIS	NMC /LFP NMC NMC	POUCH	9.1	SSE HKEX OTC	601238.SH 2238.HK GNZUF
6	GEELY	CHINA	420,480	5%	LEGACY	14	CALB CATL	NMC NMC	POUCH	9.9	HKEX OTC	HK 0175 GELYF
7	HYUNDAI	KOREA	418,632	5%	LEGACY	6	LGES SK ON	NMC NMC	POUCH	57.6	KRX LSE	055380 HYUO
8	BMW	GERMANY	378,722	4%	LEGACY	9	CATL ENVISION SAMSUNG SDI	NMC NMC LMO	PRISMATIC	56.8	FWB OTC	BMW.F BMWYY
9	STELLANTIS	FRANCE ITALY	348,422	4%	LEGACY	5	CATL SAMSUNG SDI LGES	NMC NMC NMC	POUCH	48.3	NYSE EURONEXT BORSA ITALIANA	STLA
10	SAIC	CHINA	292,032	3%	LEGACY	19	CATL SUNWODA	NMC /LFP NMC	POUCH	6.3	SSE	600104
11-20			1,369,012	16%	LEGACY							
	TOTAL		**8,510,238**	**100%**						**1.029**		

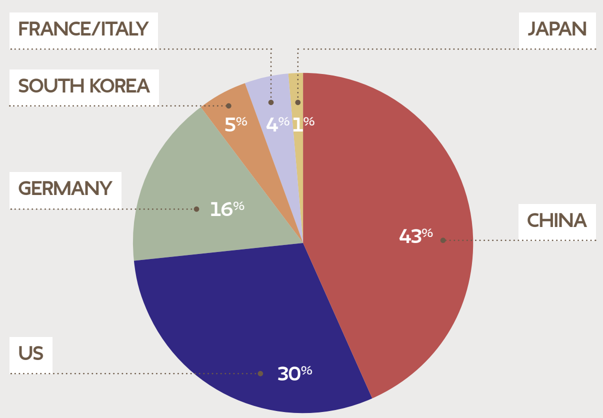
THE SOURCE OF POWER



COUNTRY BREAKDOWN - TOP 10 LIB PRODUCERS BY 2023 PRODUCTION (MWH)



COUNTRY BREAKDOWN -TOP 20 EV PRODUCERS BY 2023 PRODUCTION (UNITS)



THE TOP TEN LITHIUM-ION BATTERY MANUFACTURERS

THE SOURCE OF POWER

Table 2 reports summary data on the top ten LiB producers based on the total energy (MWh) of their LiB production in 2023. The striking feature is that the top ten consists of only three countries, China (63%), Japan (9%) and Korea (28%) as shown in the schematic on the previous pages. In fact, the top two producers CATL (37%) and BYD (18%) are both Chinese and produce 55% of the top ten market. China has six of the top ten slots, Korea has three and Japan has one. Clearly, China is the prominent power source for EVs globally and it is effectively driving every second EV on the road today.

Panasonic, the only leading LiB producer from Japan, works closely with Tesla and has a 9% market share while Korea is gaining ground currently with a 28% share of the top ten market. However, Korea is scaling up production and all three current producers from Korea in the top ten have ambitious expansion plans in Europe and the US. Kumyang, the new entrant from Korea, is expected to help catapult Korea ahead of China in the next five years. Kumyang has a superior product, a complete supply chain (from Lithium mines to cathode production, battery assembly and recycling) and a potential annual capacity to produce 36.5 GWh. Korea has the technical and production resources as well as free trade agreements with both the US and the EU.
There is likely to be a power struggle in this increasingly competitive market.

THE LIB LANDSCAPE

The schematic on the previous page illustrates the intricate linkages among the LiB producers and the EV manufacturers. China is the dominant LiB producer and imports no LiBs. The US and EU are entirely dependent on foreign producers of LiBs, however, some of the production takes place in the American and European EV manufacturers' home markets.

CATL (Contemporary Amperex Technology Ltd) is the major producer with a production of nearly a quarter of a million megawatt-hours (MWh) in 2023, it was founded as a for-purpose company in 2011 by Dr Robin Zeng. It launched an IPO on the Shenzhen Stock Exchange (SZSE) in 2018 and currently has a market capitalisation of $108.8bn which makes it more valuable than all other LiB and EV producers except Tesla. Most of CATL's production is in China although it opened a plant in Germany in December 2022 and it has announced the opening of another in Hungary in 2025. It has encountered some resistance in the US with some political overtones and it has limitations from China which restricts the number of offshore investments it is able to make. CATL's founder and CEO announced the intention to start a $1.5bn fund in Hong Kong to facilitate the global energy transition, thus signalling a strong intent to go global despite political impediments in the US and China. CATL supplies seven of the top ten EV manufacturers and specifically its LFP battery for Tesla's production in China. In addition, CATL produces the NMC cathode in the prismatic form. CATL has a share in CMOC, the Chinese mining firm, for some materials. It purchases Lithium from Australia, Argentina and Chile.

It is interesting that new purpose-created firms dominate both the LiB and EV markets.

BYD is both the second largest LiB and EV producer. As mentioned in the last section it produces LiBs for its own consumption. It was the first to fully industrialise the LFP battery in its iconic Blade (prismatic) form. BYD sources Lithium in China and Australia. BYD has global ambitions and tends to produce LiBs in proximity to its EV production facilities which are in China, Brazil, India and the US. It has recently announced its intention to build a factory in Hungary.

LGES (LG Energy Solution) was created as the battery division inside the Korean chemicals giant LG Chemicals and was spun out in 2022 and is listed on the KRX with a current market capitalisation of $55bn. LGES has a market share of 17% with a production output of 108,487 MWh in 2023. In terms of production, it is considerably larger than the other two Korean firms combined. It supplies five of the top ten global EV producers including Tesla and GM in the US, VW and Stellantis in Europe and Hyundai in its home market. It produces the NMC cathode in both cylindrical and pouch formats. LGES sources Lithium in Australia, Argentina and Chile. In addition to production facilities in Korea, it produces batteries in China, Poland and the US.

Panasonic is fourth on the list with a production of 56,560 MWh chiefly for Tesla and to a lesser extent VW. It is the only Japanese LiB producer in the top ten. It has a joint venture with Tesla in the US to produce cylindrical 21700 batteries which have an NCA cathode. Panasonic sources Lithium in Australia, Argentina and Chile. Panasonic Energy of North America (PENA) has recently announced its intention to open a new production facility in De Soto, Kansas, US, for this battery type. The LiBs are produced by a subsidiary of Panasonic, the giant Japanese electronics company founded in 1918 which trades on the Tokyo Stock Exchange (TSE) with a market capitalisation of $17.8bn. It also trades on the OTC markets in the US.

SK On ranks fifth in the top ten with a production of 40,711 MWh. It was created in 2017 within SK Innovation, part of the SK Group the Korean chaebol. It was spun out in 2021 and is listed on the KRX with a market capitalisation of $7.4bn. Its main top ten EV customers are Hyundai Motors and VW in Germany. However, it has a strong relationship with Ford in the US. It produces the NMC LiB in a pouch format. It sources its Lithium mainly in Australia but also in China, Argentina and Chile. SK On is well placed for global expansion and it has production facilities in Korea, Hungary, China and the US. There is no doubt that SK On is a pivotal participant and it is very much part of the *K-Wave* to project Korea into being the leading supplier of LiBs.

Samsung SDI is the third Korean in the top ten coming in at rank sixth with a production of 35,703 MWh. Samsung SDI was created in 1970 as a joint venture between the Korean and Japanese electronics giants, Samsung and NEC as the Samsung-Nippon Precision company and it changed its name to Samsung SDI in 1984. In the 1990s it started making Nickel-Cadium (NiCd) and Nickel-metal hydride (NiMH) batteries for use in consumer electronics. In 2000 it started producing LiBs forming a partnership with Bosch to create SB LiMotive to produce LiBs for EVs. Samsung SDI took full ownership of SB LiMotive in 2008. The company has production facilities in Korea, China, Hungary and the US. It serves all three European EV manufacturers in the top ten, VW, Stellantis and BMW. It produces NMC and LMO batteries in both the cylindrical and pouch format. It sources its Lithium in Australia, Argentina and Chile. Samsung SDI is listed on the KRX with a market capitalisation of $16.5bn. The three Korean firms on the list represent a considerable threat to the Chinese domination of the market. Collectively the Korean LiB producers have superior technology, global production systems and free trade agreements with the US and the EU, all of which augur well for the rise of the *K-Wave* in LiBs.

CALB (China Aviation Lithium Battery Technology Company) is seventh on the Table 2 list with a production of 23,493 MWh in 2023. It was founded in 2007 as a subsidiary of AVIC a state-owned enterprise and began producing LiBs in 2009. It listed on the HKSE in 2022 and has a market capitalisation of $2bn. Its customers are local, mainly GAC and Geely, and it produces the NMC LiB in all three formats: cylindrical, pouch and prismatic. CALB sources its Lithium in China, Australia, Argentina and Chile.

Farasis, **Envision** and **Sunwoda**, are the last three Chinese producers on the list in ranks eighth, ninth and tenth. They produce mainly for the local market except for Envision which has BMW as a client. They all produce NMC LiBs in the various forms and they all source their Lithium in China, Australia, Argentina and Chile. Farasis is listed on the SSE and Sunwoda on the SZSE with a GDR trading on the SIX stock exchange in Switzerland. Their market capitalisations are $1.6bn and $4.4bn respectively. Envision is a private company.

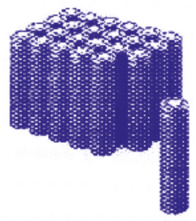
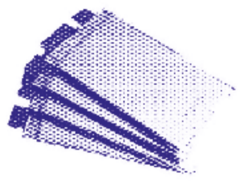
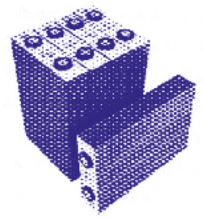
TABLE 2 The top ten Lithium-ion battery producers by 2023 production (MWh)

RANK	MANUFACTURER	COUNTRY	PRODUCTION MWH	MARKET SHARE	ORIGIN	FOUNDED	CUSTOMERS	CATHODE	FORM	MARKET CAPITALISATION ($BN)	LISTINGS	TICKER #
1	CATL	CHINA	242,700	37%	NEW	2011	TESLA GAC & SAIC GEELY VW & BMW STELLANTIS	LFP NMC/LFP NMC NMC NMC	PRISMATIC	108.8	SZSE	300750
2	BYD	CHINA	115,917	18%	BATTERY	1995	BYD	NMC/LFP	PRISMATIC	89.5	SZSE OTC	SZ: 002594 BYDDY
3	LG Energy Solution ESS Battery Division	KOREA	108,487	17%	CHEMICAL	1947	TESLA GM VW STELLANTIS HYUNDAI	NMC	CYLINDRICAL POUCH	55	KRX	(373220.KS)
4	Panasonic	JAPAN	56,560	9%	BATTERY	1918	TESLA VW	NCA	CYLINDRICAL	17.8	TSE OTC	6752TYO PCRHY
5	SK	KOREA	40,711	6%	CHEMICAL	2017	HYUNDAI VW	NMC	POUCH	7.3	KRX	096770.KS
6	SAMSUNG SAMSUNG SDI	KOREA	35,703	5%	BATTERY DIVISION	1970	VW STELLANTIS BMW	NMC NMC NMC/LMO	CYLINDRICAL PRISMATIC	16.4	KRX	006400.KS)
7	CALB	CHINA	23,493	4%	BATTERY	2007	GAC GEELY	NMC	CYLINDRICAL POUCH PRISMATIC	2.0	HKSE	HK 3931
8	FARASIS	CHINA	16,527	3%	BATTERY	2002	GAC	NMC	PRISMATIC	1.5	SSE	688567 SSH
9	Envision AESC	CHINA	8,342	1%	NISSAN BATTERY EV (NEC)	2007	BMW	NMC	CYLINDRICAL POUCH	N/A	N/A	N/A
10	SUNWODA ENERGY	CHINA	6,979	1%	BATTERY	1997	SAIC	NMC	CYLINDRICAL POUCH PRISMATIC	4.2	SZSE/SIX	300207/SWD
	TOTAL		**655,419**	**100%**						**302.8**		

LITHIUM-ION BATTERY FORM FACTORS

TABLE 3 A comparison of the key properties of the three Lithium-ion battery form factors

Within the sphere of LiB technology, there are three widely accepted, and most commonly used, cell designs, each with its own unique characteristics; advantages & disadvantages; and applications:

	CYLINDRICAL	POUCH	PRISMATIC
FORM			
ADVANTAGES	EASE OF MANUFACTURING WIDESPREAD APPLICATIONS SUPERIOR THERMAL STABILITY	FLEXIBILITY AND ADAPTABILITY WEIGHT REDUCTION COST-EFFECTIVENESS	STACKABILITY SPACE EFFICIENCY ENHANCED THERMAL PERFORMANCE
DISADVANTAGES	LACK OF SPACE EFFICIENCY INCREASED WEIGHT LIMITED DESIGN VERSATILITY	LOW-TO-MEDIUM CAPACITY RELATIVELY FRAGILE CASING	COSTLY MANUFACTURING PROCESS POTENTIAL FOR DAMAGE
MANUFACTURERS (NON-EXHAUSTIVE)	KUMYANG SAMSUNG SDI LG ENERGY SOLUTION PANASONIC	SK ON LG ENERGY SOLUTION	SAMSUNG SDI CATL BYD
CUSTOMERS (NON-EXHAUSTIVE)	TESLA RIVIAN LUCID	HYUNDAI/KIA GM FORD	BMW VW BYD

ADVANTAGES OF CYLINDRICAL CELLS

Ease of manufacturing. The cylindrical design makes itself optimal for mass production, leading to economies of scale and overall lower manufacturing costs. Each cell consists of a cylindrical metal casing that protects the internal components, including the positive and negative electrodes; separator; and electrolyte, making them safer to use.

Widespread applications. It's the most versatile form of battery as they are commonly found in a wide range of applications, including UPS systems; GPS devices; power tools; drones; e-bikes; e-scooters; and EVs.

Superior thermal stability. Cylindrical batteries tend to operate better across a broader spectrum of temperatures. Moreover, the cylindrical form factor reduces the risk of *thermal propagation*, thereby also making them safer for use owing to the lower risk of a fire.

WHAT IS THERMAL PROPAGATION?

Particularly in the use case of EVs, several charging and discharging cycles in battery cells result in heat generation inside an individual cell, which then influences adjacent battery cells. Overheating can cause thermal runaway in one or several cells, meaning the heat transfers to neighbouring cells which results in thermal propagation. The higher the number of cells, the higher the chance of a fire to propagating. However cylindrical form factors promote optimal heat dissipation owing to the absence of cell-to-cell contact.

ADVANTAGES OF POUCH CELLS

Flexibility and adaptability. Also known as a flexible or flat-cell battery, pouch cells can be easily moulded into various shapes, making them highly adaptable to irregular or unconventional designs. Unlike traditional cylindrical or prismatic cells, pouch cells are generally made by laminating flat electrodes and separators, and then sealing them in a flexible, heat-sealed pouch or bag made of a flexible material, often Aluminium. They offer up to 95% better packaging efficiency.

Weight reduction. The absence of a rigid casing reduces the overall weight of the cell, making it optimal for applications where weight is a critical factor. Pouch cells can be up to 40% lighter than steel or Aluminium-cased batteries of equal capacity.

Cost-effectiveness. The manufacturing process for pouch cells is often simpler and less resource-intensive, contributing to cost savings. Moreover, the low-cost casing helps reduce the initial cost of production.

ADVANTAGES OF PRISMATIC CELLS

Stackability. The flat shape of Lithium prismatic cells allows for easy stacking (the electrode materials are typically arranged in layers), meaning the created battery packs have higher energy density compared to cylindrical and pouch cells.

Space efficiency. Owing to their known space-efficient design, they are ideal for applications with limited space constraints. Their flat shape allows for better packaging in certain devices (often without a mounting bracket).

Enhanced thermal performance. Prismatic cells' flat design aids in heat dissipation, contributing to improved thermal performance.

DISADVANTAGES OF CYLINDRICAL CELLS

Lack of space efficiency. The cylindrical shape prevents the space (within the module) from being used to its maximum potential. The same gaps that help reduce *thermal propagation* prevent more cells from being added to the module.

Increased weight. Owing to the lack of space efficiency, more cells would be needed to reach similar power levels to the prismatic battery. The cells also need a mounting bracket to be kept in place, further adding to the weight. In use cases such as EVs, this added weight could substantially impact performance.

DISADVANTAGES OF POUCH CELLS

Low-to-medium capacity. Many pouch cells would need to be welded together to function in large-scale battery packs for industrial purposes. This poses a risk that should a fault develop, the whole module would then need to be replaced.

Relatively fragile casing. Extra protection is needed to preserve pouch cells since the casing is too weak to prevent thermal events. The cell can expand up to 10% of its original size after 500 charge cycles, thereby posing a safety concern.

DISADVANTAGES OF PRISMATIC CELLS

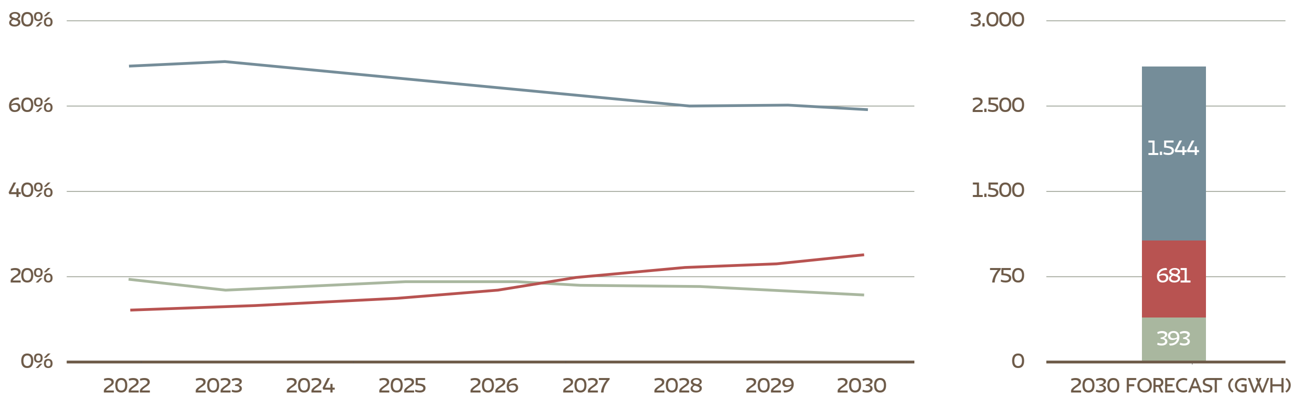
Costly manufacturing process. There is no standardised size of prismatic battery but instead several. Whilst this does imply flexibility, the drawback is that the lack of standardisation between models makes prismatic cells more costly to produce.

Potential for damage. Whilst the flat shape does have various advantages, a negative is that more stress is placed on the electrode and separator sheets closer to the container corners, which could lead to a higher risk of electrode coating damage.

Whilst prismatic cells are currently the most widely used, forecasts suggest that the market share of cylindrical batteries (compared to prismatic and pouch) is expected to rise between now and 2030 owing to superior thermal propagation and mass production of *46 series* cells, which have favourable characteristics over older models of cylindrical batteries. For example, the 4680 cell has five times greater energy and a 16% larger range than the 21700 model. The market share of prismatic cells is expected to fall up to 2030 (see Figure 2).

FIGURE 2 Forecast of the demand for Lithium-ion battery form factors

PRISMATIC
POUCH
CYLINDRICAL



OPPORTUNITIES AND CHALLENGES FACING KOREAN LITHIUM-ION BATTERY PRODUCERS

Battery technology advancements, and innovations in Lithium-ion cell design continuing to drive progress in energy storage solutions, undoubtedly portend a more interesting LiB market in the coming years. Not only will end-users continue to receive a plethora of choices, but battery manufacturers, such as Kumyang, will be driving each other to develop better systems that will blaze the trail towards net zero.

This push towards carbon neutrality presents numerous opportunities at three distinct levels: company; industry; and state-wide. However, to properly evaluate how sustainable and realistic these ongoing initiatives are, the potential challenges must also be considered along with the aforementioned opportunities. This section aims to do just that.

OPPORTUNITIES

Large projected demand growth for LiBs. Whilst there are margins for uncertainty over exact figures, consensus forecasts show a dramatic rise in demand for LiBs, predominately driven by the automotive industry. According to a study by the Fraunhofer Institute, total LiB demand was approximately 420 GWh in 2021, with more than 50% allocated to the automotive sector. In 2030, projections vary from 2 to 4 TWh corresponding to a CAGR of 19% (assuming 2 TWh), of which automotive applications are expected to account for roughly 80%. This presents an obvious opportunity for current and prospective battery manufacturers if executed correctly in the sector's competitive landscape. Continuous and multifaceted research into this technology will be of paramount importance (see *Challenges* below).

Kumyang's 4695 superior cylindrical battery. As more R&D has been carried out and published, an increasing number of high-profile automakers are now looking to apply *46 series* secondary batteries to their new platform of EVs. Examples include BMW's *Neue Klasse*; Rivian; and Lucid. Moreover, preliminary data indicate that Kumyang's 4695 cylindrical battery is, by various metrics, superior to Tesla's 4680 with 44% greater driving range etc. (see *Benchmarking the Kumyang 4695*). If approached correctly, this presents Kumyang an opportunity to launch its customer base for LiBs and/or forge new OEM agreements with automakers such as Tesla.

Diversification away from China. Stemming from the political sphere and rising geo-political tension with China, there's mounting pressure on European companies to 'de-risk' from the world's second-largest economy, with pleas from high-profile politicians such as Ursula von der Leyen, President of the European Commission, and Olaf Scholz, Chancellor of Germany. Mr Scholz adopted the country's first-ever official China strategy in 2023, calling for German companies to diversify their supply chains and export markets away from China, thereby reducing Germany's vulnerability to external shocks. With this comes long-term opportunities for other LiB-producing markets like South Korea. The recent surge in Chinese direct investments from German companies (€7.3bn in 1H24) may serve as an indicator of the general sentiment over the increased likelihood of more stringent European China policies in the coming years. In fact, after a detailed year-long investigation, the EU Commission has already concluded that the EV value chain in China benefits from unfair subsidisation and lower labour costs. Therefore, it has recommended import tariffs on Chinese and non-Chinese automakers from 17% - 38%, depending on the degree of company cooperation with the investigation. These tariffs could have the consequence of non-Chinese automakers being economically forced to diversify their EV supply chains in the long term.

Investment into EV charging infrastructure. To accelerate the commercialisation of EVs, there needs to be massive investment into recharging stations and infrastructure across urban and rural areas. More charging stations could prove to be an integral factor in creating greater long-term demand for EVs (and therein LiBs), as universal access to this crucial infrastructure is still somewhat limited. This investment has already been commenced by governments across the globe, including South Korea. Various other recent political initiatives in South Korea also augur well for the LiB sector (expanded on next).

Auspicious environmental policies in South Korea. Following the implementation of the Korean Green New Deal in 2020 by former President Moon Jae-in, which included a pledge to expand the supply of electric vehicles and rapid charging points, the current South Korean government has maintained this strategic focus and is adjusting its subsidy policies for electric vehicles and charging infrastructure to promote Korean e-mobility. By 2030, they aim to have 4.2 million electric vehicles and a total of 1.2 million public and private charging points. The government has lowered the subsidy amount for purchasing an electric vehicle but widened the eligibility scope, meaning a greater number of vehicles now qualify for a subsidy. Moreover, the government has raised its subsidy budget for charging infrastructure by 60%. Whilst it's still unclear what exact impact this will have, it has great potential to increase demand for EVs within the South Korean market. LiB producers, such as Kumyang, are well placed to capitalise on such a trend given their numerous competitive advantages (see *Kumyang K-Value Chain*).

Proliferation of smart grids. The development of novel *smart grids* capable of recharging without overloading the electrical system, via an approach called *vehicle to the grid*, will ensure that the owners of EVs receive some money by selling some of the stored energy in the batteries back to the grid, while such excess energy could be stored intermittently. With current laws on emissions for the automotive sector becoming more stringent, this combines an environmental opportunity with a financial incentive. Therefore, in a similar fashion to how investment into EV charging infrastructure may stoke greater long-term demand for EVs, the growth of *smart grids* could have a similar consequence.

Growing need for end-of-life solutions. The projected growth of electric vehicles will eventually lead to large quantities of LiBs that are not suitable for use. According to an article by McKinsey & Co., the global second-life electric vehicle battery supply is to rise from 1 GWh in 2020 to 15 GWh in 2025 and reach between 112 - 227 GWh by 2030. This raises a critical need for proper, scalable and sustainable end-of-life solutions for EV battery packs if the forecasted demand growth for LiBs is to be sustained, presenting an economic opportunity if appropriately sized.

CHALLENGES

Fierce industry competition**.** As shown in Table 2, there are numerous established large competitors in China and Kumyang's home market, South Korea. How easily Kumyang will be able to grow in this already saturated market will depend entirely on how effectively it can demonstrate its value proposition and the competitive edge of its 4695 cylindrical battery, as already mentioned. Continual active research to enhance their battery characteristics will be critical given ongoing innovation and contrasting competition currently between secondary batteries used in the automotive industry and used in other applications like UPS systems; power tools; and medical devices.

Declining cost of secondary batteries. Owing to significant ongoing research initiatives and the evolution of technological concepts, the cost of batteries is likely to continue declining over time, especially in the case of the LiB. For example, between 2000 and 2018, its cost reduced drastically, with the cost in 2010 being 17% higher than in 2018. A high cost of production can act, amongst others, as a barrier to entry to this industry. If LiB costs continue to fall, it is likely to entice more competition to enter the market. However, this may be somewhat mitigated by the large intellectual and technological expertise (other typical barriers to entry) needed to compete and ultimately succeed in this industry.

Accelerated mining and extraction of raw materials. The surge in battery manufacturing and production in recent years to meet the demand for EVs has drawn a lot of attention to the increasing extraction of raw materials, through mining, and the pressure it puts both on the environment and individual natural resources such as Lithium; Nickel; and Cobalt. Whilst most agree that the planet has enough reserves to meet short-term demand over the next few years, there remains uncertainty of whether we have enough for 100% electrification of the transport sector, representing an obvious barrier to sustainability and growth for LiB producers in the long term.

Disposal of LiBs. LiBs pose an environmental and safety risk if they are not treated properly at the end of their lives in EVs. Moreover, disposal, one of five possible end-of-life solutions (the other four being reuse; restoring; recycling; and incineration), might be necessary due to the hazardous nature of the batteries and the risks they might expose workers to. Besides the obvious environmental fallout, this could lead to long-term reputation damage for the industry if this issue is not addressed. Therefore, the need for scaling other sustainable end-of-life solutions (see *Opportunities*) is imperative.

Rising cost of electricity**.** The increasing demand for electricity owing to the growing demand for EVs, and the subsequent increased cost of power, is one of the main concerns reducing the public acceptance of replacing existing internal combustion engines. The same public perception has the potential to negatively influence the LiB industry. Moreover, whilst large-scale investment in recharging infrastructure from governments presents an obvious opportunity for the EV and LiB industries, it also comes at a cost which will have a ripple effect on the cost of electricity. If electricity prices rise in the short to medium term, combined with a possible fall in fuel prices, it may disincentivise individuals to switch to an EV.

Other energy sources. Fossil fuel prices may fall in the short to medium term, possibly through a de-escalation of tensions between Russia and the Ukraine, making it financially more difficult for consumers to switch to other, more eco-friendly, concepts technologically. Separately, the proliferation of Iron phosphate LFP secondary batteries could prove to be a challenge for Kumyang's new 4695 LiB model. As previously mentioned, Tesla has recently started buying LFP batteries from CATL for its production in China. However, whilst other forms of LiB technology are continuously being developed, the NMCA type's superior chemical properties (see *Lithium-ion Battery…the Lion King*) will sustain demand for them over other chemical forms.

KUMYANG K-VALUE CHAIN

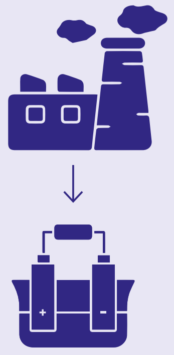
ABOUT KUMYANG

Kumyang Co., Ltd. (Kumyang) has surpassed its reputation as the first company in South Korea to localise the production of chemical blowing agents (substances whose atomic structure allows them to expand), becoming the world leader in this field, and the developer of the world's first eco-friendly blowing agents. Founded in 1955, and listed on the KOSPI since 1976, Kumyang now serves over 7,000 customers in 76 countries and owns and operates several facilities across Asia; the US; and Europe. Their products are used in, amongst others, automotive interior components; wallpaper; shoes; swimsuits; and insulation materials. Kumyang's customers include the likes of BMW; Nike; and Adidas. The company is now investing heavily in the area of secondary battery production and materials. They have secured a stable supply of critical minerals through resource development and developed the unique capability to produce the world's only ultra-high-Ni (Nickel) single-crystal cathode materials. Kumyang has pioneered by building a Lithium-ion cylindrical battery K-Value Chain in Korea, which includes the mass production of such batteries. Based on this value chain, Kumyang will mass-produce high-quality cylindrical LiBs using their purer ultra-high Nickel single-crystal cathode materials, positioning the company as a global leader in this market. Through the reinvestment of profits and continuous research and development,Kumyang is committed to maintaining superior technology and cost competitiveness while becoming a pioneer in green technology innovation.

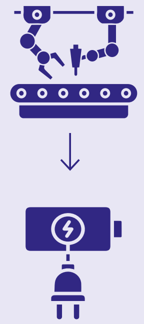
STAGE 1
TOTAL MINING AREA
$98\ KM^2$
13,725 SOCCER FIELDS

STAGE 2
REFINES RAW MATERIALS FROM IMPURITIES
ANNUAL PRODUCTION CAPACITY
10,000 TONNES

STAGE 3
SMLAB DRY PRODUCTION
ULTRA-HIGH NICKEL CATHODE MATERIALS
ANNUAL PRODUCTION CAPACITY
MORE THAN 42,000 TONNES



STAGE 4
PROPRIETARY CYLINDRICAL LIBS
ELECTRODE CREATION; ASSEMBLY; FORMATION; AND PACKAGING
CARRIED OUT INTERNALLY
$124,000\ M^2$ MEGA FACTORY IN GIJANG, SOUTH KOREA
ENERGY STORAGE (ESS); E-MOBILITY



STAGE 1

MINERAL RESOURCES DEVELOPMENT

Kumyang is securing essential minerals for secondary battery production through mine development.
The company acquired a 44 km^2 mineral mine in Mongolia in June 2023 and another in the Democratic Republic of Congo in December 2022 (54 km^2) to secure a stable supply of the metals. The total mining area equates to 13,725 soccer fields.
The various procured critical raw materials such as Lithium and Manganese, after being initially processed through mine development, are essential for creating LiB cathode materials in stage three of the *K-Value Chain*.

STAGE 2

REFINING AND PROCESSING MATERIALS

Kumyang's Lithium hydroxide crushing and processing business refines the raw materials and removes impurities *via*, amongst other steps, sieving and magnetic filtering. External contamination is blocked through sealing and automatic operation.
Its annual production capacity is 10,000 tonnes, and they also supply various mixed products to other domestic cathode material manufacturers (mixing of mineral materials is essential for improving the performance of cathode materials).

STAGE 3

PRODUCING BATTERY MATERIALS

With its unique technology, SMLAB (Kumyang's affiliated company) mass produces ultra-high Nickel (>97% Ni) and Lithium & Manganese-rich single-crystalline cathode materials through a *dry production* process (the only company in the world to adopt such a method). Cathode materials are one of four core materials in secondary batteries.

As of June 2023, SMLAB possesses a facility capable of producing 10,800 tonnes annually. In March 2026, another facility with a monthly capacity of 2,600 tonnes is scheduled to be completed, ensuring a total annual production capacity of more than 42,000 tonnes.

STAGE 4

MANUFACTURING BATTERIES

Kumyang completes the final stage of the *K-Value Chain* through the in-house manufacturing of their proprietary cylindrical LiBs, with innovative technology from raw material mining; refining; and cathode material processing. All four battery manufacturing processes within this stage are carried out internally: electrode creation; assembly; formation; and packaging.

The company is about to complete constructing a 124,000 m^2 mega factory in Gijang, South Korea. With a maximum annual capacity of 36.5 GWh, all of Kumyang's future batteries will be made here for uses in energy storage (ESS); electric vehicles; and other forms of e-mobility (see *Kumyang the rising force in Korean Lithium-ion battery production*).

BENCHMARKING THE KUMYANG 4695

The Kumyang 4695 (KY INR4695-340E) represents a new standard LiB which Kumyang will be launching in scale in 2025. It uses an NMCA cathode with a pure form of Nickel (98%) in a single-crystal structure. The 4695 has considerably improved the properties of both the 21700 and even the Tesla 4680.

The customers for LiBs are interested primarily in those properties of the battery that contribute significantly to the range, charging speed and longevity at an effective cost both financially and environmentally.

WHAT DETERMINES RANGE?

The key properties of the LiB that contribute to the range are:

Energy Density represents the amount of energy stored in the battery per unit volume (Wh/l), and per unit weight (known as specific energy measured in Watt-hours per kilogram (Wh/kg)). The greater the energy density the greater the range for a given space, and the greater the specific energy the lower the contribution of weight to the EV and the greater the range.

Energy Capacity is the storage capacity measured in Watt hours (Wh) which is equal to **discharge capacity** ((Amp hours (Ah)) times Voltage (V)). The more energy available the further the range.

Discharge Rate (Amperes (A)) measures the speed at which the LiB delivers energy relative to its capacity. It may be measured in C units which is a multiple of the battery's capacity. Efficient discharge at a given level of required power ensures that EVs sustain long-range mobility. The higher the C rate the better as the LiB is able to deliver the energy rapidly and more efficiently sustaining long-range driving. It directly affects acceleration too.

Impedance (Mega Ohms (MΩ)) is a measure of the opposition a battery offers to a current flow and is a composite measure of resistance as well as inductance and capacitance.

There are many other factors affecting range including the state of charge range (SOC), the effective usable capacity between maxima and minima requirements. The efficiency of converting chemical to electrical energy, the cycle life which represents the number of charge/discharge cycles a battery is able to endure, will affect the lifetime range of the EV. Thermal management, whereby the battery maintains operating capability within a wide temperature the range, extends range too.

WHAT DETERMINES CHARGING SPEED?

The key properties contributing to charging speed are:

Charge Rate (Amperes (A)) measures the rate at which the LiB receives energy during charging. It may be measured in C units which is a multiple of the battery's capacity. The higher the C value the shorter the charging time. A C value of unity means a charge time of an hour, and a C value of 3 implies a charge time of 20 minutes.

Impedance, as described above, affects charge times, the higher the impedance the longer the charge times. Many other factors affect charging speed including, *inter alia*, battery chemistry and temperature.

WHAT DETERMINES THE LONGEVITY OF THE LIB?

Cycle Life is the key metric for longevity, and it measures how many charge/discharge cycles the battery is able to endure. This measure represents the number of times a battery is able to be recharged. The principal drivers of longevity are battery chemistry, which influences the rate of degradation; calendar ageing; impedance; electrolyte decomposition and *inter alia*, charge and discharge rates which may accelerate the rate of degradation of the battery.

Table 4 below reports the key properties of the three LiB batteries in order to compare their performance. These are the 21700, the Tesla 4680 and the Kumyang 4695.

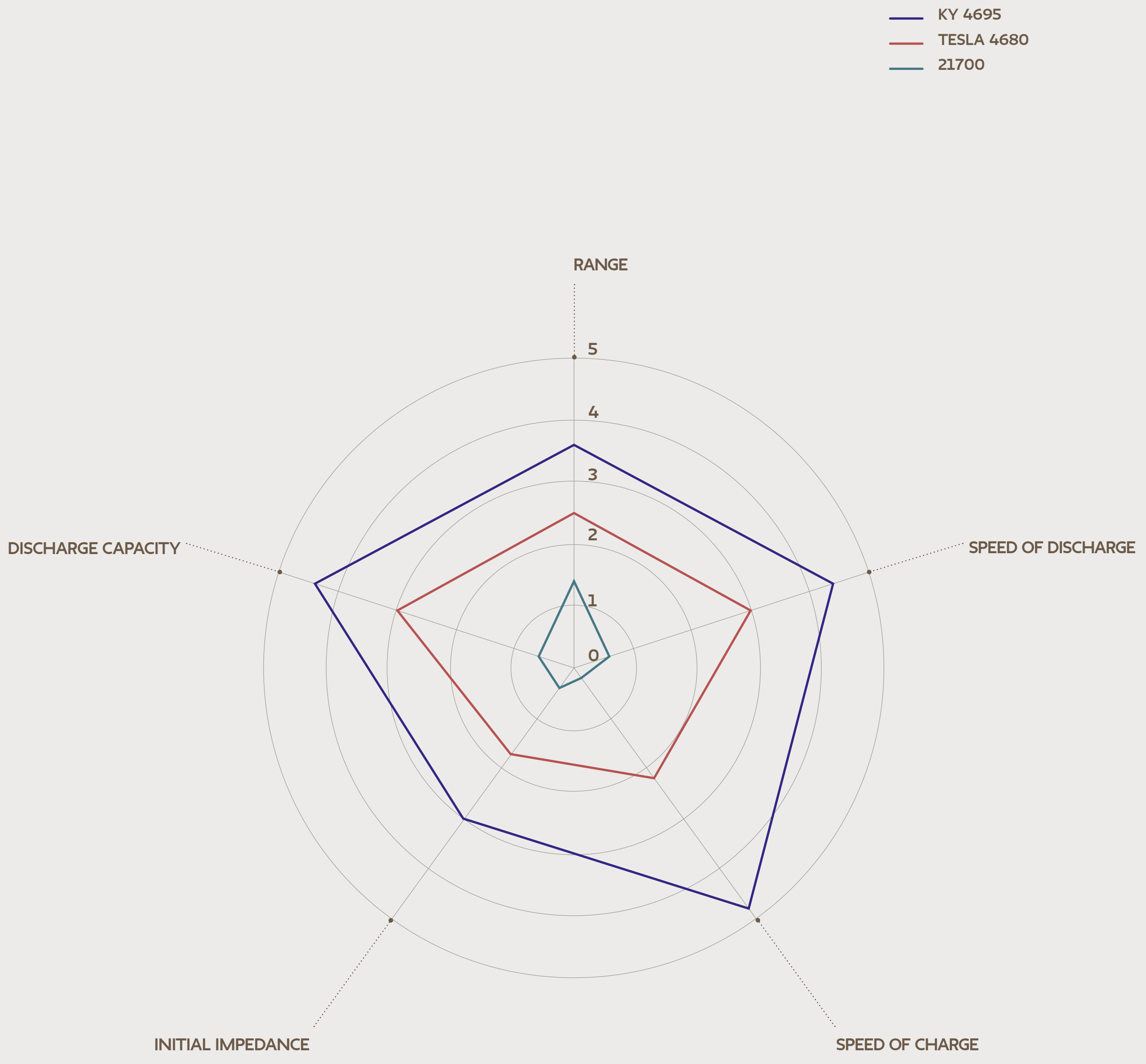
Notice that Table 4 organises the properties into seven groups; groups 1 to 4 cover battery features namely, capacity, charging, discharging and impedance; groups 5 and 6 report the performance outcomes, namely range and longevity; group 7 reports some additional features. The column on the extreme right of the table reports the improvements of the Kumyang 4695 cell over the Tesla 4680 cell. Although the Kumyang 4695 does not appear to improve longevity, it improves range by approximately 45% in both the 600 and 1,000 cell formats, increasing the range by 184 km and 308 km respectively, while also improving charge time by 33% reducing it from 30 minutes to 20 minutes. In addition, the discharge rates improve by 31%. Interestingly, although the 4695 has a 44% larger energy storage it improves energy density by 22%. This suggests that the 45% improvement in the range is only partially due to a better energy density. The other factors are the improved impedance and most importantly the use of 98% pure Nickel in the NCMA cathode. This battery defines a new standard of performance.

The radar diagram reports five key factors from Table 4 and highlights the importance of each in the comparison of the three LiBs. The data reported in Table 4 for each factor on the radar diagram is scaled from 1 to 5 in terms of performance. For example, in the case of impedance a lower score represents a higher performance therefore the reciprocal is used to scale the vector. The diagram shows the dominance of the Kumyang 4695 over the Tesla 4680 and the latter's dominance over the 21700 in all five dimensions.

TABLE 4 A comparison of the key properties of the 21700, Tesla 4680 and the Kumyang 4695

ITEM	PROPERTIES	UNITS	KY 21700	TESLA 4680	KY 4695	KY 4695 IMPROVEMENT ON TESLA
1	CAPACITY					
1.1	DISCHARGE CAPACITY	AH	5	23.4	34	45%
1.2	ENERGY STORAGE	WH	18.5	86.4	124.8	44%
1.3	ENERGY DENSITY	WH/L	763	649.8	790.3	22%
1.4	SPECIFIC ENERGY	WH/KG	272	243.4	290.2	19%
1.5	NOMINAL VOLTAGE	V	3.7	3.7	3.7	-
2	CHARGING					
2.1	CHARGE CONSTANT VOLTAGE	V	4.2	4.2	4.2	-
2.2	CHARGE CONSTANT CURRENT	A	1.4	4.7	10.2	117%
2.3	CHARGE MAX. CURRENT	A	4.9	46.7	102	118%
2.4	CHARGE RATE MAX. CURRENT	C	1	2	3	50%
3	DISCHARGING					
3.1	DISCHARGE END VOLTAGE	V	2.5	2.5	2.5	-
3.2	DISCHARGE CONSTANT CURRENT	A	0.98	4.7	6.8	45%
3.3	DISCHARGE MAX. CURRENT	A	14.7	70	102	46%
3.4	DISCHARGE RATE MAX. CURRENT	C	3	3	3	0%
4	IMPEDANCE (SOC 33%)					
4.1	INITIAL IMPEDANCE AC	MΩ	15	2.2	1.5	30%
4.2	INITIAL IMPEDANCE DC	MΩ	25	5	3.5	30%
5	RANGE					
5.1	RANGE 600 CELL	KM	N/A	416	600	44%
5.2	RANGE 1000 CELL	KM	N/A	692	1000	45%
6	OTHER METRICS					
6.1	LONGEVITY (CYCLE LIFE)	CYCLE	1600	1000	1000	0%
6.2	CELL COUNT	#	2,596	897	600	33%

KUMYANG 4695 DOMINATES



KUMYANG THE RISING FORCE IN KOREAN LITHIUM-ION BATTERY PRODUCTION

CHINA POWERS AHEAD...FOR NOW

China and Korea represent 90% of world LiB production by the top ten producers and this was evenly shared between the two in 2022. In 2023 China's share soared to 63% against Korea's 28%. This loss of market share taken together with the current decline in the global sales growth rate in EVs, presents significant challenges to the Korean LiB sector.

However, three strong change vectors will reverse this trend and allow Korea to regain its position as a lead producer with the market expecting an annual growth rate of 25% for the next decade, notwithstanding the current transient slowdown.

Firstly, deglobalisation is providing impediments to world trade. Chinese EV manufacturers are being specifically targeted with heavy tariffs; the US and Canada have recently announced a tariff of 100% on Chinese EVs and the European Commission has announced a range of tariffs between 17% and 38%. As all Chinese EVs use Chinese-made LiBs, this is an effective tariff on LiBs. Korea has FTAs (free trade agreements) with both the US and the EU placing it at a considerable competitive advantage over China.

Secondly, the Korean government has invested $38bn in the sector for research and additional capacity.

Thirdly, Kumyang is launching the most advanced LiB with a significant production capacity, making it a rising force in the Korean LiB sector.

KOREA STRIVING TO BE GLOBAL NUMBER ONE...KUMYANG THE RISING FORCE

A new force in the form of Kumyang is about to lift the Korean LiB capacity by 15%. Kumyang is in the final stages of completing its new production facility in Gijang, near the southern port city of Busan, the largest port in Korea. This facility has the capacity of 36.5 GWh *per annum* which will catapult them into the third rank of Korean LiB producers ahead of Samsung SDI and placing them sixth in the world based on 2023 production.

Kumyang has a considerable advantage in technology and cost. Kumyang introduces a complete value chain to the Korean LiB industry; from Lithium mining and processing (in the DRC and Mongolia) to advanced cathode production including single crystal technology and 98% quality Nickel (through their affiliate SMLAB); state of the art AI managed production and full recyclability. Kumyang has also built in sustainable technology with a set of responsible climate-sensitive protocols. In short, Kumyang has the most technically advanced facility producing the most efficient battery in a completely secure supply chain.

Kumyang's technology dominates existing batteries, and its research efforts are enhancing LiBs, with a solid-state electrolyte in its grasp within two years. It is experimenting with Sodium-based cathodes is showing promise. In 2026 Kumyang expects to produce LiBs for three million EVs.

KUMYANG'S PROVENANCE AND FUTURE

Since its founding in 1955, Kumyang has surpassed its reputation by becoming a world leader in the chemical blowing agent business. With its stellar track record; infrastructure; technical expertise it has acquired over many years; and the long-term vision of its senior management, Kumyang is now striving to become the pre-eminent provider of cylindrical LiBs, that maximise power; range; and safety.

The company is developing the highest density and heat-stable cylindrical cells by applying the world's first single-crystalline NMCA cathode materials, whilst simultaneously achieving the highest mass production yield through *smart* factories. The NMCA single-crystal high-density cathode material is one of the competitive advantages of Kumyang's *46 series* battery, the 4695, over the rest of the market. As mentioned, the battery has higher energy density and faster charging speed (as shown in Table 4), as well as being safer; and more competitively priced. Furthermore, the 4695 model's higher energy density, stemming from the ultra-high Nickel and Lithium & Manganese-rich single-crystal cathode materials, results in an increased driving distance (if mounted in an EV). For example, 600 Kumyang 4695 cells translates to 75 kWh energy, equalling circa 600 km driving distance. The same number of Tesla 4680 cells translates to 52 kWh of energy, equalling a driving distance of 416 km. Therefore, the 4695 has a 44% larger range.

Moreover, Kumyang is on a mission to secure cost competitiveness through its establishment of a *K-Value Chain* (see pp. 28&29), and the ability to scale through the expansion of its production facilities. As previously mentioned, the company is about to finish constructing a mega factory in Gijang, South Korea, which has a projected output of 300 million cylindrical LiBs annually.

With several strategies and initiatives already ongoing, Kumyang is making continuous progress in realising this vision and successfully commercialising their various cylindrical LiB models, with the e-mobility market (e.g., e-bikes; e-scooters; and electric vehicles) standing first on their application roadmap. In fact, an e-scooter battery pack containing Kumyang's 21700 cells is currently being verified, and mass production is planned from 2H24. They will be supplying South Korea's number one e-scooter supplier. Additionally, NDA signings with potential international customers to supply 4695 cells for electric vehicles have already been initiated. Kumyang aims to be fully supplying the EV market by 2026. The company is also exploring original equipment manufacturer (OEM) agreements for large-scale (over 1 GWh annually) customers alongside their strategic investments in overseas cell factories.

FIGURE SOURCES

FIGURE 1: SNE Research

FIGURE 2: SNE Research

TABLE SOURCES

TABLE 1: Corporate reports, Bloomberg, EV-Volumes.com, International Energy Agency, Motley Fool

TABLE 2: Corporate reports, Blackridge Research, Bloomberg, International Energy Agency

TABLE 3: Grepow

TABLE 4: Kumyang technical reports

FOOTNOTES AND SOURCES

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NOTES

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ENERGY & MINING
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hues reflect Kumyang's bra
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